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Agent-Based Participatory Simulations: Merging Multi-Agent Systems and Role-Playing Games

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Abstract

In 2001, Olivier Barreteau proposed to jointly use multi-agent systems and role-playing games for purposes of research, training and negotiation support in the field of renewable resource management. This joint use was later labeled the "MAS/RPG methodology" and this approach is one of the foundation stones of the ComMod movement. In this article, we present an alternative method called "agent-based participatory simulations". These simulations are multi-agent systems where human participants control some of the agents. The experiments we conducted prove that it is possible to successfully merge multi-agent systems and role-playing games. We argue that agent-based participatory simulations are also a significant improvement over the MAS/RPG approach, opening new perspectives and solving some of the problems generated by the joint use of role-playing games and multi-agent systems. The advantages are at least threefold. Because all interactions are computer mediated, they can be recorded and this record can be processed and used to improve the understanding of participants and organizers alike. Because of the merge, agent-based participatory simulations decrease the distance between the agent-based model and the behavior of participants. Agent-based participatory simulations allow for computer-based improvements such as the introduction of eliciting assistant agents with learning capabilities.

Keywords:
Agent-Based Participatory Simulations, Multi-Agent Systems, Role-Playing Games, Validation, Negotiation Support Tool

Introduction

1.1

Agent-based simulations are commonly used to model human social behaviors. Designers of agent-based simulations, and notably simulations of collective use of natural renewable resources, have seen role-playing games as a path towards the participatory design of their agent-based simulations. Referring to this process, the phrase "Companion Modelling" was coined by researchers committed to this approach, who created a group called ComMod (Barreteau 2003).

1.2

Not only are role-playing games a powerful tool to model social behaviors but they can also be

used to support negotiation and to train participants. Because games are known to have influence on the studied stakeholders, the ComMod group elaborated a charter to define the specificity of their approach and to limit the scope of their research activities.

1.3

While the ComMod charter does not specify a method, ComMod researchers usually rely on the joint use of agent-based simulations (multi-agent systems, MAS) and role-playing games (RPG). In fact, the use of the MAS/RPG approach is so widespread that ComMod and MAS/RPG are often understood as synonyms, even if variants of the MAS/RPG approach have been used for Companion Modelling, such as SelfCormas (d'Aquino et al. 2003).

1.4

In this article, we present a new approach, called "agent-based participatory simulations", in which role-playing games and agent-based simulations are merged. We describe the advantages of this method over the MAS/RPG approach for companion modelling.

1.5

We conducted eleven agent-based participatory simulations based on three models. The first model was derived from the El Farol Bar problem (Arthur 1994). The second model was built to study the formation of coalitions on the coffee market. The third model addressed renewable resource management and was built as an epitome of the ComMod approach within the Ecole ComMod research project. These simulations allowed us to refine the method presented in this article.

1.6

This article is divided as follows: in the first part, we describe the MAS/RPG approach and the outcomes of such participatory experiments. The second part depicts the design of agent-based participatory simulations. We especially insist on the differences between the evolution of the model of the studied social behavior in agent-based participatory simulations and the transformation of agent-based simulations into role-playing games in the MAS/RPG approach. The third part presents the specificities of the agent-based participatory simulation experiments and stresses their advantages over other kinds of participatory experiments aiming at similar goals.

Background

The MAS/RPG approach

2.1

The MAS/RPG (Multi-Agent Systems/Role-Playing Games) approach was defined by Olivier Barreteau as the methodological coupling of role-playing games and agent-based simulations (Barreteau 1998; Barreteau and Bousquet 1999). This method has also been called "Games and Multi-Agent Based Simulations" (GMABS) (Adamatti et al. 2005).

2.2

Inheriting from the methodological tradition of the computer simulations used for modeling (Fishwick 1994; Drogoul et al. 2003), the MAS/RPG approach is depicted as an iterative process. Olivier Barreteau graphically represents the process as reproduced on figure 1. The diagram combines multi-agent systems, role-playing games and observations in a two-cycle method.

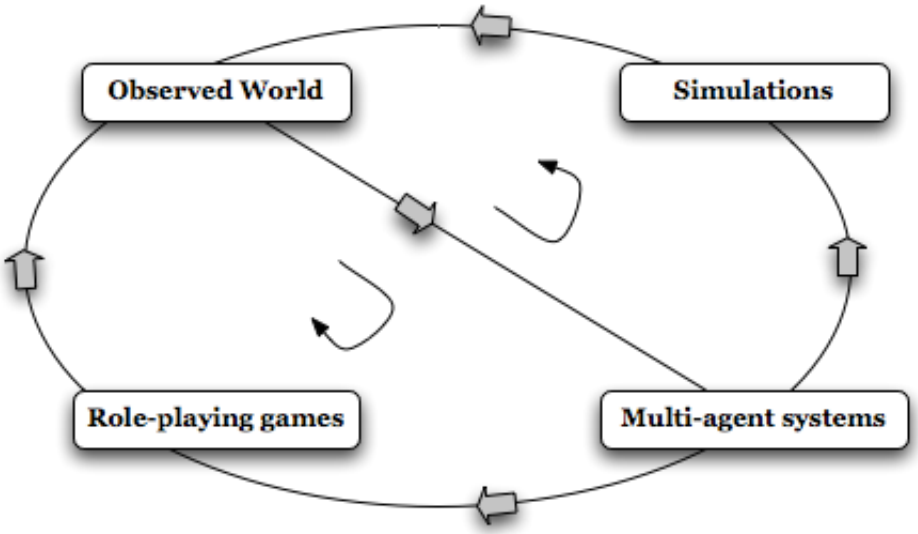

Figure 1. The MAS/RPG process (from Barreteau and Bousquet 2001)

2.3

In practice, Olivier Barreteau and other researchers who have adopted this method first proceed by creating an agent-based simulation of a given phenomenon. Most of the researchers of the ComMod group use the Cormas simulation platform (Bousquet et al. 1998), although some use Excel-based simulations (Etienne 2003). In the ComMod tradition, what is at stake is the collective management of a renewable resource. In most cases the created computer simulation is dual: a cellular automaton represents the evolution of the environment and the resource, and the multi-agent system simulates the behaviors of the stakeholders. Figure 2 represents the duality of such MAS/RPG experiments.

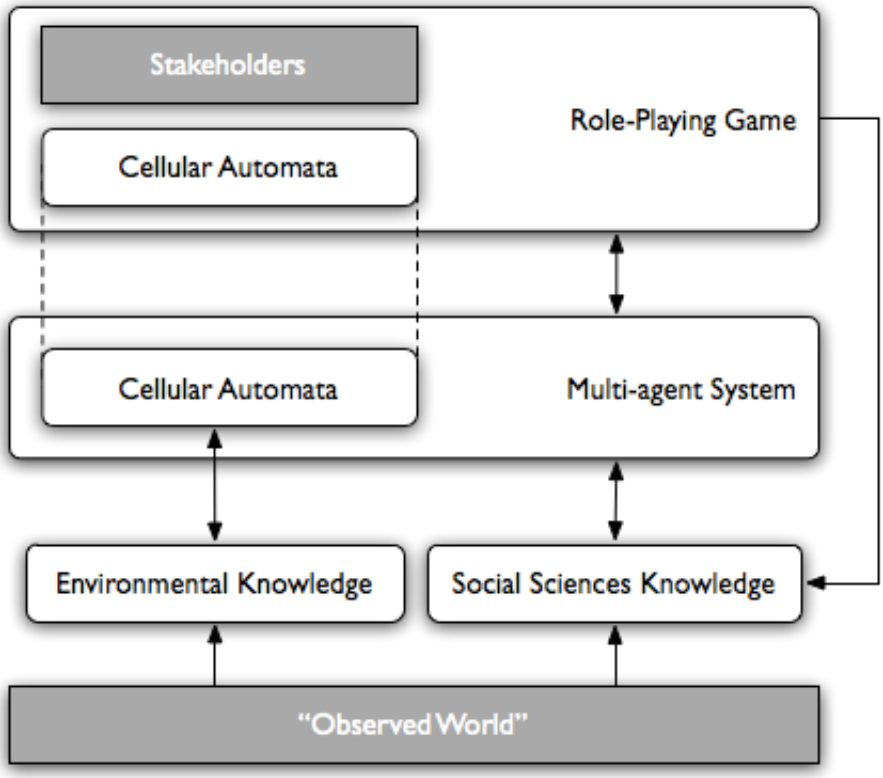

Figure 2. A dual MAS/RPG process, with a cellular automata and a multi-agent system

2.4

The designed agent-based simulation is then converted into a role-playing game. The conversion involves a simplification of many aspects of the multi-agent system. The number of agents and the number of rules in the multi-agent system are often too high for a role-playing game and consequently, the first step of the simplification is to significantly reduce the dimensions of the model (Barreteau et al. 2001). Several other parameters are changed to simplify the model while keeping the aspects the researchers want to focus on. This

simplification process is sometimes performed with the help of stakeholders themselves: discussing with stakeholders allows researchers to choose a restricted number of significant symbols that will be used during the game.

2.5

More importantly, the game is tailored to provoke reactions from the participants. For example, in SylvopastJeu, a game built by Michel Etienne to study the development of sylvopastoral systems in French Mediterranean forests, fire deterministically breaks out in the middle of the game instead of obeying a validated model of actual fire outbreaks (Etienne 2003). This way of triggering reactions from participants by creating problematic or annoying situations is reminiscent of techniques used by social scientists, such as ethnomethodological breaching which consists in breaching the social order to study the way it is maintained (Garfinkel 1967).

2.6

In role-playing games based on renewable resource management, the dynamics of the resource are computed by a cellular automaton that has the same rules as the cellular automaton coupled to the multi-agent system (figure 2). The interface between the cellular automaton and the role-playing game can be implemented in various ways. One method consists in asking participants to fill out forms and then entering the collected data into the computer (figure 3). The game is sometimes clearly divided into a negotiation phase, where participants discuss freely, and a decision phase, where they fill out the forms. The cellular automaton computes the outcome of the participants' actions and the result is displayed on the computer screen or printed on new forms that will be used to make the decisions for the next turn.

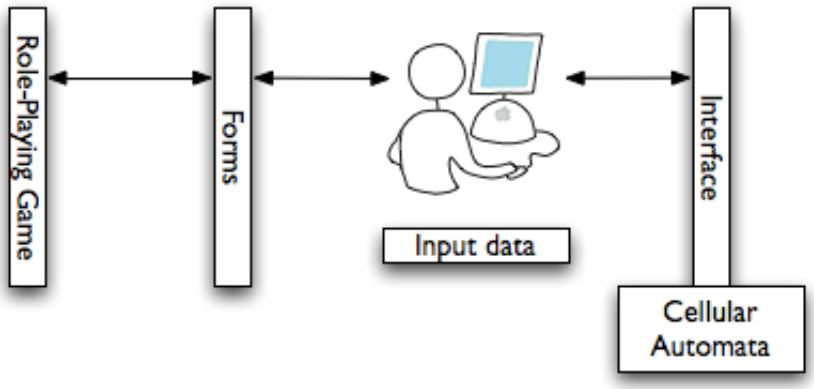

Figure 3. Practical operation of JogoMan (from Adamatti et al. 2005)

2.7

A debriefing session is organized after the game. While it does not explicitly appear in the diagram drawn by Olivier Barreteau, debriefing is probably the most important part of the approach. It allows participants to provide feedback about the game and this key element is a requirement for validation (Bousquet 2001): the feedback of the participants enables researchers to validate and improve their model, as well as the agent-based simulation.

Three kinds of participatory experiments

2.8

It is possible to build a typology of participatory experiments from their goal (Guyot and Drogoul 2005b). Role-playing games are known to have three serious or non-ludic uses (Barreteau et al. 2001): training, observation and negotiation support. These three uses coincide with the three outcomes of participatory experiments and the three goals of participatory action research: education, sociological research and action.

2.9

Training and education is the most widespread serious use of role-playing games. The games designed for training are exercises with fictitious stakes. They aim at improving the reactions of participants in specific situations. Scenarios include exceptional, yet plausible, elements. The environment is real or realistic. Examples of such games include simulations of military missions (Swartout et al. 2006) and exercises to learn how to deal with the weaknesses of an organization in a crisis situation, such as evacuations or terrorist attacks (Toth 1988).

Participatory simulations designed for education often focus on teaching the link between individual and collective behaviors, for example by asking students to analyze the propagation of a virus implemented with infra-red communicating smart tags they wear and that represent symptoms with diodes (Resnick et al. 1998).

2.10

Role-playing games are also organized to observe the behaviors of participants. The goal of this kind of games is usually to test an hypothesis, or, more generally, to answer a scientific question. The environment is not necessarily realistic. However, the stakes are often real because the underlying theory requires that the motivation of participants be driven by what can be earned in the game. For example, in games based on economic theory, participants can earn real money depending on a measure of their success during the experiment, such as the amount of fictitious money they have earned (Camerer 2003). This kind of games are not designed to be fun but are rather based on the idea that participants behave in the game as they do in real life and that they will consequently use the same strategies. Such experiments are sometimes followed by a debriefing session in order to better understand the motivations and the behaviors of participants (Lederman 1992).

2.11

The third use of role-playing games is action as defined by researchers of the Participatory Action Research tradition (Wadsworth 1998). This kind of games focus on individual and collective learning, stressing on the collective behavior to adopt in order to solve a common problem. Such games can be used to favor negotiation between participants or simply to help them discuss (Tsuchiya 1998). Stakes are fictitious but the environment is realistic. In some cases, the representations involved in the game are chosen by the participants themselves, so as to foster discussion (d'Aquino et al. 2003). In participatory experiments used to support negotiation, the roles are sometimes exchanged to allow participants to better understand the point of view of other stakeholders in real situations (Etienne 2003).

2.12

While most experiments do not belong to a single use, the chosen method depends on what organizers want to focus on. For example, the way debriefing sessions are organized depends on what researchers expect from the experiments (Peters et al. 1998). Besides, participatory experiments are frequently tested with students before being implemented with stakeholders. In such cases, the same model first has a training purpose and then is used as a support for negotiation.

2.13

Agent-based participatory simulations inherit from the tradition of participatory simulations and can be similarly used with the same three objectives: education, research and action.

Design of agent-based participatory simulations

3.1

The agent-based participatory simulations process is represented by the iterative diagram reproduced on figure 4. This process consists in designing the simulation, conducting the experiments, organizing debriefing sessions and analyzing the result. The design of the simulations is characterized by successive transformations of the model, the definition of primitives and the implementation of the computer interface.

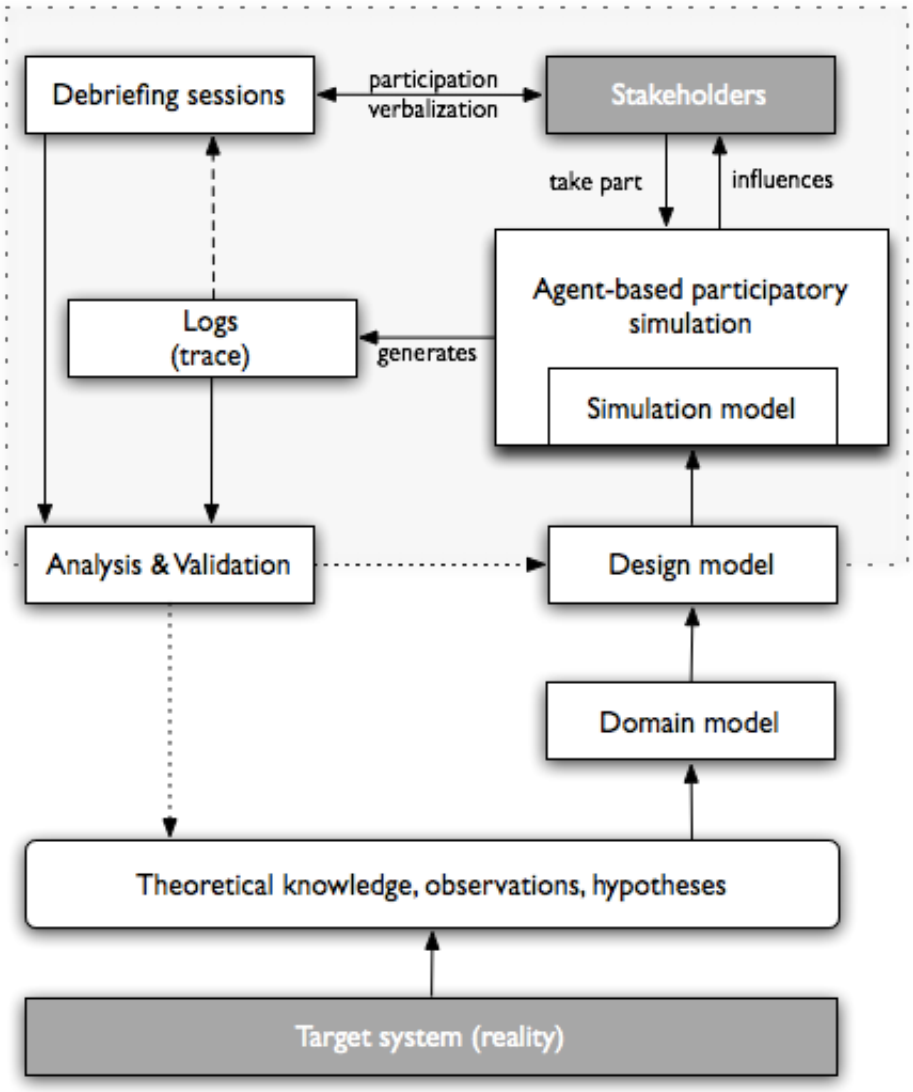

Figure 4. Agent-based participatory simulation process

Transformations of the model

3.2

Like experiments following the MAS/RPG approach, agent-based participatory simulations are designed from a model of the target system. Drawing from descriptions of the design of agent-based simulations, this original model is called the "domain model". In the case of the coffee market of the state of Veracruz, the domain model was a description of the interactions between coffee producers and coffee buyers. It also described how the coffee is produced and distinguished three roles of producers for three steps of the coffee production (growers, owners of "beneficio seco" and owners of "beneficio húmedo").

3.3

The domain model is then transformed into a "design model" that includes formal descriptions of the elements at stake. The details of this model are understood and can be discussed by both computer scientists and specialists of the target system being simulated. In the case of the coffee market, the domain model consisted in UML diagrams focusing on the important points of the model. For example, it included a sequence diagram for the transportation of coffee or use case diagrams to describe the various models of coalition on the market. In these diagrams, the coalition was initiated by a request from a buyer and was based on three interaction protocols for coalition formation: coalitions based on cooperatives, coalitions based on bids, like ContractNet (Smith 1980), and coalitions based on one-to-one negotiations.

3.4

The design model is then modified to yield the "simulation model". The modifications are driven by the need to adapt to the constraints and the goals of the experiments. Such a transformation is related to the simplification process used to transform the agent-based simulation into the role-playing game in the MAS/RPG approach. Indeed, the simulation model, being used for a

laboratory experiment, cannot have the same dimensions as the domain model, which describes reality. Besides, the main constraint is to make the model simple enough to be explained and understood quickly by the participants. This may require important simplifications. Nevertheless, for the same reason that the role-playing game in the MAS/RPG approach must be close enough to reality for participants to adopt a realistic behavior, the simulation model must be close enough to the domain model. In the example of the coffee market, the simulation model was simplified and focused on the case of coalitions between producers of "pergamino" coffee (owners of "beneficio húmedo"). This part of the production was considered to be the most important by producers we interviewed. Besides, the transport risk was completely eliminated in order to focus on the formation of coalitions when producers do not have enough coffee in stock.

Definition of primitives

3.5

We decided to break the formal descriptions of the interactions between agents as specified by the design model (the interaction protocol) into primitives or primitive actions. What is meant by "primitives" is the minimum unit of interaction or action. For example, the interaction protocols describing how agents negotiate in the design model consist of the Contract Net protocol, one-to-one negotiation and membership to cooperatives. The primitives common to these three protocols include sending money, sending coffee or sending a text message to another producer.

3.6

Primitives are a key feature of agent-based participatory simulations. Because possible actions are divided into primitives, participants are not bound to a specific interaction protocol and in particular, to the interaction protocol described in the design model. Instead, they can create an infinity of protocols with the same granularity as the original protocols. This property is required for validation as models of social behavior cannot be validated if participants are forced to follow predetermined interaction patterns. Besides, experiments showed that non-matching behaviors are the most interesting and yield improvements to the domain model. For example, in simulations of coalitions on the coffee market, a trader behavior emerged that proved more efficient than the original coalition behavior (Guyot et al. 2005a). This behavior could only emerge because participants were able to create their own interaction protocols.

3.7

Primitives define the effectors of the agents controlled by the participants. In agent-based participatory experiments, participants embody the control architecture of agents: the graphical user interface allow participants to replace the reasoning model of the agent (where a cognitive agent could be based on a BDI model) and the primitives allow them to follow or invent any interaction protocol where a traditional cognitive agent would use a library of common interaction protocols.

The Simulación framework

3.8

All the experiments we conducted were based on the Simulación framework. Simulación is a set of about 300 Java classes allowing to quickly design a computer interface for the participants (figure 5). Relying on multi-agent technologies (every entity on the network behaves like an agent), applications based on the Simulación framework are robust enough to tackle the problems that may occur in the course of the experiments (network failure, bugs, etc.). Simulación also handles the localization of the user interface. Applications can be displayed in several languages and the text shown to users can be edited by non-programmers, for example in order to translate the interface into the native language of participants. We conducted experiments in English, French, Japanese, Spanish and Thai. Participants are, of course, able to use non latin characters when they discuss in their native language.

Figure 5. The user interface of SimCafé, an application based on Simulación

3.9

Furthermore, the Simulación framework allows experiments to be conducted over wide-area networks such as the Internet (Guyot and Drogoul 2005a). Organizing online experiments raises two problems. The first problem is that the presence of the organizer is often required during the game. Participants need to be helped with the computer interface. This problem was easily solved during the first experiment based on the El Farol bar game theory problem: the program included an interface allowing participants to interact with the organizers during the game in order to receive online help.

3.10

The physical presence of the organizers can also be required to supplement the computer interface to the game. Organizers may need to control precisely the information the user interface displays upon requests of participants. For example, in Sylvopast, a role-playing game where participants directly interact with a single computer, organizers are particularly interested in what data participants refer to, such as the age of trees or the risk of fire, and how they combine them in order to make their decisions (Etienne 2003). To study this behavior, organizers do not want participants to guess that some information is available by manipulating the game user interface, but instead they wait for participants to request the information and then show it to them on the user interface. As a consequence, Sylvopast cannot be played remotely and online. Simulación solves this problem by providing a simple natural language processing module that allows organizers to define the information participants can gain access to. This module enables participants to access hidden information by typing their request in natural language, such as "show me the age of trees".

3.11

The second problem raised by distant experiments is the organization of the debriefing session. While modern technologies available for Internet-based communications such as video-conferencing or text-based chat can be used for this purpose, it is difficult to replace a meeting right after the simulation, in a single room with all the participants. This is why, although since 2004 the Simulación framework has made Internet-based simulations possible, we have only organized one online experiment. However, the same technology makes it easier to conduct experiments across several rooms in a same building. We noticed that being alone in a room when playing slightly modifies the way participants perceive the game and the others. Because they do not witness all interactions that may occur between organizers and other participants, they are unsure as to what other participants know. This echoes many real life situations and

can be used to study behavior based on differential knowledge (Guyot et al. 2006).

The experiments

4.1

The most visible difference between MAS/RPG experiments and agent-based participatory simulations is the number of computers involved. In MAS/RPG experiments, there is always a single computer for each experiment. The computer is often controlled by the organizers who enter data and read the output of the cellular automaton. In some cases, the computer is controlled by participants themselves under the supervision of the organizers (Etienne 2003).

4.2

On the contrary, in agent-based participatory experiments each participant is sitting at a computer (figure 6). Additional computers can be used to control software agents, to compute the evolution of the environment and to record the actions of the participants.

Agent-based experiments

Figure 6. An agent-based participatory simulation. Each participant sits at a computer

4.3

Agent-based participatory simulations are agent-based because each participant controls an agent and behaves exactly as if they were part of an agent-based simulation. Participants exclusively interact through the agent they control. This is enforced by dispatching participants in several rooms or by supervising them. This yields two advantages of agent-based participatory simulations over other kind of participatory experiments.

4.4

The first advantage concerns a major difficulty with participatory experiments: participants do not have an objective overview of their behaviors. When computer science students are asked to implement their own behavior, the result is closer to an ideal behavior (Sempé et al. 2006) or to theory than to their real strategies, even if those were more efficient (Grosz et al. 2004). When

participants are stakeholders, they often refuse to admit their behaviors because of the importance of underlying stakes. To be able to confront what participants say during the debriefing session with what they actually did, Michel Etienne records the game with a video camera. In agent-based participatory simulations, all actions of participants and all interactions between participants are recorded and there is no need to use a video camera that might not catch all aspects of the negotiation between participants. The record, taking the form of an XML log, is more faithful than what participants can say and it can be very easily processed before and during the debriefing session using an XML stylesheet transformation. Information extracted from the logs can also be used to trigger reactions during the debriefing sessions by telling participants what they precisely did or said during the simulation and by asking them to comment on it.

4.5

Another problem of the MAS/RPG approach is that while it aims at building a better agent-based simulation from what occurred during the role-playing game, there is still an important gap between what participants do during the game and what agents do in the simulation. A large part of the behavior of participants during the game, namely negotiations and discussions, is not formalized with agent-based interactions and is not computer-mediated. This discrepancy requires to bring modifications to the domain model and to formalize the behavior of participants in the role-playing games in order to modify the agent-based model. Consequently, more iterations of the role-playing game are necessary to validate the modifications gradually brought to the agent-based model. On the contrary, since participants of agent-based participatory simulations control agents and exclusively interact through their agents, their entire behavior takes the form of agent-based actions and interactions. This behavior is recorded in the log and can be referred to when improving the agent-based model. Besides, an analyzer, based on genetic programming, was built to automatically extract interaction patterns from the logs in order to more easily implement the participants' strategies within an agent-based simulation.

The Assistant Agent

4.6

By seating each participant at a computer, agent-based participatory simulations make it possible to introduce innovative interface items that improve role-playing games. Starting with experiments based on natural resource management conducted in November 2005, we introduced assistant agents designed with two goals in mind: to help participants better understand the dynamics of the resource and to help them better explain what their strategies were.

4.7

The assistant agent makes suggestions to the participants (figure 7). The suggestions are based on a model of a good strategy for the game combined with a learning mechanism. For example, in the experiments based on natural resource management, the assistant agents of the harvesters suggested the best cells considering the number of harvesters and the complex rules of harvest. The learning mechanism was a simple reinforcement technique based on the colors of the cells the participant had previously chosen. This intended to reproduce a common mistake of participants: they chose to harvest the darkest cells. The rules of harvest, however, are such that if all participants adopt this very strategy, it yields a lower harvest.

Figure 7. The assistant agent making suggestions and asking questions

4.8

When the participant does not follow the suggestion, the assistant agent asks why. The suggestions and the replies are logged for offline analysis and can be mentioned during the debriefing session. The interaction with their assistant agents exhorts participants to verbalize during the game and raises their understanding of the model. Participants better explained their strategies during the debriefing session when they had to think about them as they discussed with their assistant agents.

Reducing the guilt

4.9

In most games based on renewable resource management, the parameters of the game are chosen to yield badly valued results, as part of the breaching methodology. For example, in the ButorStar game designed by Raphaël Mathevet, participants have to agree on an irrigation plan and when they do not, the computer program chooses the worst plan (Mathevet et al. 2005). Likewise, in SylvoPast, a fire breaks out if the shepherd is eliminated from the game (Etienne 2003). The experiments based on natural resource management we conducted belonged to the same tradition: they were based on the CherIng MAS/RPG game whose parameters are tailored to yield the disappearance of the resource if participants do not collaborate.

4.10

While such a feature belongs to a breaching approach, it can also arouse guilt among participants, especially if the stakes are emotive issues such as protecting an endangered species. In our experiments, the assistant agent was perceived by the participants as an embodiment of the organizers. Because participants did not realize the suggestions were based

on features of their past decisions, they considered that even the assistant agent, and therefore even the organizers, could make bad decisions. Comparing themselves with the organizers decreased their feeling of guilt while maintaining the breaching effect.

Agent-based participatory simulations as an evolution of the MAS/RPG approach

4.11

Agent-based participatory simulations, by merging multi-agent systems and role-playing games, could be understood as an alternative of the MAS/RPG approach where the process is based on a single kind of simulation and where each participant acts as the control architecture of an agent.

4.12

In fact, agent-based participatory simulations are a natural evolution of the MAS/RPG method as several elements of MAS/RPG experiments can be analyzed as the first steps towards a merge of the multi-agent system and the role-playing game. For example, the use of Cormas during role-playing games to simulate the cellular automaton representing the environment means that participants have an agent-based interface to the environment: the interaction between participants exclusively take place through the role-playing game, but their actions on the environment, which is based on forms or cards in the game, are translated into agent-based actions by the organizer in order to let Cormas compute the consequence on the environment. In some cases, Cormas even simulate very simple reactive agents to represent entities of the environment such as endangered birds.

4.13

The merge of the multi-agent system and the role-playing game does not diminish the scope of such participatory approaches. Indeed, the mediation of an agent-based simulation, where participants are able to freely discuss through the exchange of text messages, does not impose any additional constraint compared to the mediation of the role-playing game, where participants must follow the rules of the environment, the social rules and their roles. The interactions with the organizers that allow participants to redefine their roles and the social rules are matched by the use of primitives that allow participants to freely follow any strategy.

 Conclusion

5.1

Agent-based participatory experiments are an evolution of the MAS/RPG approach where the role-playing game and the multi-agent system are merged. As a consequence, the outcomes of agent-based participatory simulations are directly inherited from the outcomes of the MAS/RPG approach. They can be used for three goals: training and education, research, and as a support for negotiation. Agent-based participatory simulations differ from the MAS/RPG approach on three main points that correspond to three significant advantages.

5.2

The first main difference and advantage is that since all actions and all interactions take place through computers, they can be recorded. Recording everything improves the observation and particularly helps organizers pursuing the research goal. Besides, the records can be processed easily during the debriefing sessions and participants can more easily be confronted with what they actually did during the game. The records can also be used to trigger reactions by making it possible for organizers to mention precisely what participants did and said during the experiments.

5.3

The second difference and advantage over the MAS/RPG approach is that, unlike role-playing games, agent-based participatory simulations are agent-based. Indeed, they can be considered as multi-agent systems where some agents are controlled by the participants. As such, the agent-based participatory approach decreases the gap between the agent model and the game the participants are involved in. This facilitates the design and the tuning of an agent-based simulation that represents the behavior of the participants.

5.4

The third main difference and advantage is that since each participant is seated at a computer, it is possible to enrich the interface of the game to improve the outcomes of the experiments. In particular, the introduction of an assistant agent with learning capabilities improved the understanding of the model by the participants. By asking participants to comment on their decisions during the game, this assistant agent enhanced the discussion during the debriefing sessions.

5.5

Not only are agent-based participatory simulations an evolution of the MAS/RPG approach, but they are also a new kind of hybrid simulations opening new perspectives for the participatory design of agent-based simulations.

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Return to Contents of this issue